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FEDERAL COMMUNICATIONS COMMISSION
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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In re **Amendment of the Commission's Rules to Establish a Single AM Radio Stereophonic Transmitting Equipment Standard**	**ET Docket No. 92-298** **Reply Comments of** **Leonard R. Kahn**

Leonard R. Kahn, as the developer of one of the two AM Stereo systems that is competing in the free marketplace, wishes to offer reply comments opposing the subject NPRM, because it is based on false assumptions, will mandate the use of a fatally flawed system and violates the Federal Communications Act, 47 United States Code. Moreover, the Commission's staff, acting under severe political pressure was unwilling to even permit a ten-day delay,[1] so that broadcasters would have time to voice their opinions regarding a decision that threatens the very survival of AM radio broadcasting.

In summary, Kahn replies to Motorola that its system was rejected by broadcasters and now it must be rejected by the Commission, because of its technically fatal flaws that make its

[1]The undersigned has received telephone calls from irate broadcasters from all over the country asking why the FCC has set such an unreasonable schedule for replies to probably the most important proceeding the Commission has ever authorized. The instant reply was rushed to a point that Kahn believes that he has been denied a reasonable opportunity to present his case.

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use inconsistent with the Commission's policy favoring improving, not the destroying, the AM broadcast service, and because its anticompetitive behavior in the marketplace in violation of the law disqualifies its system from being selected by the Commission pursuant to The Federal Communications Act.

COMMENTS

Leonard R. Kahn ("Kahn")[2] opposes the adoption of the Motorola system for stereophonic AM broadcast service in view of the system's serious deficiencies and because its adoption would violate the rules of the Commission.

As the Commission will note, Motorola's comments are singularly free of any attempt at arguing its system's technical merits, but rather repeats its unfounded claims to the number of **users** of its system.[3] The confidential section of this reply will further address the real reasons for Motorola having **any**

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[2]For Kahn's professional qualifications to comment on this NPRM, please see page two of his Comments filed on April 5, 1993. In view of certain statements in the instant Reply he wishes to point out that he appeared as a witness at the Senate subcommittee hearing that led to this NPRM and that he is a Patent Agent, licensed to practice before The United States Trademark and Patent Office on patent matters since 1973.

He is President and CEO of Kahn Communications, Inc., the first recipient of FCC type acceptance of an AM Stereo Exciter.

[3]Each FCC decision maker should pick up a phone and spot check stations in areas where Motorola claims it still has **users** of its stereo system....and check if any leaves it on at night?

stations at all using its flawed system.[4] Thus, most of the following reply comments will be directed to the comments by broadcasters who address the real issues in selecting a technical standard,[5] i.e., how each candidate system's performance will impact on broadcast service. Clearly, the replies should make even lay Commission staff members realize that they need impartial, high-level, engineering advice, something they cannot expect from individuals who are paid for their lobbying efforts.

RESPONSES TO THE NPRM WERE UNFAVORABLE TO MOTOROLA BUT MOST FAVORABLE TO THE SELECTION OF ISB AM STEREO

The clear majority of the comments oppose the Commission's

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[4]The Commission has a substantial amount of data on file that proves the "fatal flaws" of the Motorola system. For example, in 1980, Mr. David Hershberger, of Harris, Mr. Robert Streeter, of Phillips/Magnavox and the undersigned all filed reports to the Commission (based on measurements and mathematical analysis), proving that the Motorola system creates severe interference, in violation of FCC rules. This bandwidth problem will dead-end AM radio, as it will deny AM radio the opportunity to introduce new and advanced narrowband technology. Besides the inherent bandwidth flaw, the Motorola system has the overwhelming disadvantage of being a phase separation system which creates "platform motion" making its use inappropriate for night time operation for most stations.

[5]Unfortunately, there is insufficient time to properly

first quick response to the mandate to select a system. Actually, not only do they request the Commission to try again, but the system of preference is the so-called Kahn ISB system. This result is most impressive in view of the biased wording of NPRM and in view of Motorola's all time most expensive marketing effort directed at the broadcast industry.[6]

Clearly, the majority favors the Commission's selecting a system on merit, not questionable success in the marketplace where Motorola has destroyed free competition by making certain that radios that receive other types of stereo signals are excluded.

Most of the commentors have pointed out that:

a) Motorola is not the industry's favorite, and

b) they want the "best" system, not the <u>politically</u> right system.

Selection of a system whose technical deficiencies preclude many stations' use of AM Stereo will only further injure AM broadcasting.

<u>REPLY TO JUST TWO COMMENTS</u>

<u>Even the inventor of the "Harris Linear System" Favors ISB Sideband Stereo:</u>

Capitol Cities/ABC correctly opposes the Motorola system.

Its engineers know something is wrong, because they can hear it and see it on their spectrum analyzers all over the country. Amusingly, ABC selected the system that the Harris Corporation abandoned,[7,8] but more importantly, the system's developer and original proponent, Mr. David Hershberger, also abandoned it, but for the correct engineering reasons. He discarded the QUAM system because it is a "phase" perturbation-sensitive system i.e., a "phase separation" system, that makes the system subject provide the best performance.[9] However, in the iterim, i.e., for at least the next twenty years, the so-called Kahn ISB system is superior, because it does not produce an envelope with a cusp for negative modulation that restricts effective modulation. See Exh. 1, an early publication by the undersigned analyzing the envelope of a linear SSB wave and also cited earlier papers.

In Mr. David Hershberger's carefully thought out submission, he details the reasons why Motorola system could not be used; including, the "platform motion," and then proposed a linear independent sideband system.

The undersigned fully supports a linear independent sideband system. He has been involved in the development of linear SSB systems for some 40 years and, indeed, invented the system that was used by Harris to provide linear quadrature modulation and the system that would be used to implement linear SSB. However, unfortunately, the existence of literally hundreds of millions of conventional AM receivers with envelope detectors precludes the use of such a system by the vast majority of stations who would never willingly restrict their modulation and curtail service to a significant number of their listeners.

The problem is the "cusp" like nature of the envelope function of a linear SSB system. (see Exh. 1)

However, the undersigned believes that the linear system is

[9]The undersigned must hedge a little, because a transmitter for the linear ISB system is somewhat more difficult to design. Kahn Communications is presently engaged in the development of high-efficiency, high-powered (up to 1 megawatt) transmitters for AM, linear SSB, AM Stereo and POWER-side. (Exh. 2)

the ultimate system by allowing broadcasters to use the present system that has been thoroughly tested and which is still effectively competing in the marketplace because of its that operate in stereo all of the time, night and day, under good listening conditions or under the worst. **They will be able to make radios without stereo/mono automatic mode switchers or blenders.** The only reason Motorola and Harris needed receivers that switched to mono was **"platform motion." No platform motion...full time stereo.** And since platform motion disappears when a Kahn ISB demodulator is used, **even listeners to Motorola stations will enjoy a tremendous improvement!**

<u>But what will Motorola stations penalties be</u>?

a) Their stereo imaging will be degraded, but most listeners will find the sound much better than stereo with platform motion and the stereo switching on and off; and

b) They will still suffer from loss of mono coverage due to the excessive bandwidth of the Motorola signal.

Thus, Motorola-equipped stations will actually be better off then they are now and many will probably turn their equipment back on.

<u>How will the Harris-equipped stations find the switch</u>?

a) Their stereo imaging will be degraded, but their listeners will also still find the sound better, absent "plat-mo."

b) They too will still suffer from loss of coverage, not due to excessive bandwidth (Harris' bandwidth was excellent), but rather due to poor negative modulation characteristics.

<u>And how will Kahn ISB equipped stations like the switch</u>?

a) Great

b) Just great.

But why shouldn't there be an advantage for stations who listen to their engineers and invest in superior technology?

For the few hundred Motorola users (and those 500 or so owners of such equipment) who wish to enjoy, full-time, platform-free operation, the (b)-item loss of coverage will induce them to switch over to full Kahn ISB system operation. This will not only allow them to serve more of their listeners, but it will allow their adjacent channel neighbors to get relief from their excessive splatter, letting these innocent parties serve more listeners.

[The necessary equipment to convert their equipment will be substantially less than the original investment the Motorola stations made in stereo, and Kahn Communications, Inc. will offer conversion kits to such stations and, indeed, provide other manufacturers design licenses to market such kits.]

Thus, all AM stations,[11] not only AM Stereo stations, should be happy.

But what about those people who bought Motorola only receivers?

That is a problem. But not for the reason one might think. Those people are not tuning to AM stereo stations because they are operating in stereo. If they were there would have been a mad rush to buy (not accept no-cost packages) Motorola system exciters.

In any case, if the Commission picks the Kahn ISB system,

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[11]Including stations with "problem" antennas that cannot be used with the Motorola system. Such stations are generally low on the dial with severe protection requirements that cannot be "broadbanded" by conventional means without losing significant amounts of effective radiated power. Kahn Communications' "Flatterer" can be used to ease such problems, but it is not an inexpensive device and only equipment has been designed for use with mono, Kahn ISB stereo and POWER-side signals. (Exh. 2)

Kahn stations can, in the matter of minutes, switch their pilot tones from 15 Hz to 25 Hz. (Indeed, some stations using the Kahn ISB system conducted experiments with a Motorola pilot, but when they heard the results they quickly switched back.)

The problem with that is, although the listeners heard stereo, they also heard **platform motion!!!! And the radios popped in and out of stereo!!! A true disaster.**

But even though it may offend those in the Congress who think broadcasters, unlike radio receiver manufacturers,[12] cannot be trusted to make their own decisions, the undersigned wishes to make a marketplace decision. Allow any broadcaster, Kahn or Motorola, the choice of using 15 or 25 Hz pilots. If he picks 25 Hz and he uses the Motorola system, everything will be "normal," but he will have platform motion and on-and-off stereo. If he values his reputation he probably rejected that situation. However, if he just serves a small town and he is a daytimer, he (or she) may accept the situation.

On the other hand, if the station uses Kahn ISB it generally serves larger areas and he will find it best to wait for the new radios that will meet the new FCC standards. However, that will be their choice and they will have freedom to switch at any time. Indeed he might switch at sundown each day, as may Motorola

[12]It is interesting to read EIA's comments. They favor the Commission forcing broadcasters to use the Motorola system, but they are suddenly in favor of free enterprise when it comes to allowing receiver manufacturers to make mono only radios with 2.8 Khz frequency response that have been destroying the reputation of AM for the last two decades.

stations.[13]

The danger of trusting broadcasters with such freedom, (can one imagine such a discussion between Americans), is that if they don't make the correct choice, their listeners will come to the conclusion that AM Stereo is a form of low-fidelity torture.

But, out of the few stations that have bought Motorola equipment and still use it, many turn off stereo operation at night on their own. Thus, one can expect the vast majority of stations that have rejected the Motorola system, will, if the Commission selects the Kahn ISB system, install Kahn type ISB stereo exciters and eschew the freedom to use a Motorola pilot.

RECOMMENDATIONS

[The undersigned, after (hurriedly) studying the comments to this NPRM believes that the vast majority of the comments confirm his original recommendations which he now repeats.]

Kahn respectfully requests the Commission to carefully and deliberately reevaluate its NPRM. AM radio should not be considered a minor matter to the Commission while it ponders what it perceives is more newsworthy subject matter. More people rely on the 1 Mhz of spectrum devoted to AM radio than any other service, and those listeners deserve a full hearing. He further respectfully requests the Commission to seek advice from the National Institute of Standards and Technology ("NIST") in the

[13]In case someone is concerned about patents, Kahn was granted the original patent on the pilot and, of course, while he staked out 15 Hz because of its low frequency and harmonic relationship to 60 Hz, the claims are not that narrow.

selection of a system that will allow AM stations to make use of the best technology available to compete in their all important marketplace competition with FM, cable, cassettes, etc., etc.

AM radio deserves the best technology available...its very survival depends upon it.

Dated: April 19, 1993

Respectfully yours,

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EXHIBIT 1

[redacted]

As pointed out in Appendix I, the above comparison is based upon an assumption of plate circuit efficiency for the Class C amplifier of 80 per cent. In both the linear and the envelope elimination and restoration transmitter calculations, we have not taken into consideration loss in the rf coupling networks but since both systems should have approximately the same loss in these circuits, the comparison would not require modification. If we had assumed that the Class C amplifier had a plate circuit efficiency of 75 per cent, the power output of the envelope elimination and restoration system would be 2.1 times as great as that from a linear amplifier system.

Comparison of Means of Modification of High Level AM Transmitters to Single-Sideband Operation

Many firms are reluctant to convert to single-sideband transmission because of the expense of completely replacing AM transmitting equipment. Therefore, there has been considerable interest in proposals for converting AM transmitters to single-sideband operation.

One method proposed is to use envelope elimination and restoration adapters. The second method proposed is to redesign the transmitter for Class B linear operation. This second technique would require appreciable engineering effort and in many cases additional stages would have to be added to make up for the decreased power gain of Class B linear amplifiers. Also, since frequency multipliers are not linear devices, further radical changes would be necessary.

It might be interesting to compare the power output from a high-level amplitude modulated transmitter converted to linear amplifier operation with the power output from the same transmitter utilizing an envelope elimination and restoration adapter.

In Appendix II, it is shown that a high-level amplitude modulated transmitter, if modified for Class B linear single-sideband operation, would have a peak envelope power rating of approximately two-thirds of the carrier rating of the transmitter. If such a transmitter was adapted by the envelope elimination and restoration system, the peak envelope power would be equal to approximately four times the carrier rating for single-sideband telephone operation. The rating of such a transmitter when transmitting multichannel teleprinter single-sideband signals varies between three to four times the carrier rating of the AM transmitter depending upon the number of tones transmitted and whether they are phase-locked. Thus we see that for telephone operation there is a power gain of approximately 6 and for a multichannel teleprinter a power gain of 4.5 to 6 over the power output from a high level modulated transmitter converted to Class B linear operation. If, in the above calculations, a figure of 75 per cent was assumed for the plate circuit efficiency of the final Class C stage, the power gain of the envelope elimination and restoration system, over the linear amplifier system, would be 3.37 to 4.5 times.

It should be noted that the above comparison was based upon the assumption that a modulator for the transmitter was available. If a modulator is not available, it would be necessary to compare the cost of the modulator plus the envelope elimination and restoration adapter with the cost of engineering, labor, and the power disadvantage of converting the rf stages of the transmitter to Class B linear operation.

The above calculations are based upon the carrier rating of an AM transmitter. If the cw rating of the transmitter is used, the peak envelope power of the Class B linear is two-thirds the value above stated or approximately four-ninths of the cw rating of the transmitter. Similarly the peak envelope power of the envelope elimination and restoration adapter transmitter for single-sideband telephone operation is approximately 2.67 times the cw rating and from 2 to 2.67 times the cw rating for multichannel teleprinter operation.

Required Modulator Response

Table I is a tabulation of the required modulator frequency response for given spurious outputs from an envelope elimination and restoration transmitter.

TABLE I

Modulator equalized to pass up to	Worse spurious level for two equal tones
Fundamental of the difference frequency of the two equal tones	−25.3 db relative to 1 of the two tones
Second harmonic	−31.4 db
Third harmonic	−36.2 db
Fourth harmonic	−40.5 db

In the paper published in 1952 [1], a similar chart was furnished based upon the assumption that all the energy in the components not passed by the modulator added up to produce a single spurious component. That chart was therefore pessimistic as pointed out in that article. A new mathematical technique has since been developed [5] and the fact that the figures originally published were pessimistic was confirmed.

In Appendix III, this new technique is used to solve this problem. *However, it should be pointed out that these figures are still pessimistic because the analysis assumes that two equal amplitude tones are radiated and their frequencies are at the extreme ends of the transmitted band.* Of course, in practice, voice signals have most of their high energy components situated at relatively close spacing at the low-frequency end of the audio band. Another reason why these figures are pessimistic is that in most applications there are many components transmitted simultaneously rather than just the severe two-tone case. Multichannel telegraph single-sideband, and of course voice systems, normally radiate more than two-tones simultaneously.

If, instead of two equal tones, tones of unequal amplitude are transmitted, the frequency response requirements of the modulator are eased.

Another important reason why these figures are quite conservative, is that the response of a conventional amplitude modulator does not suddenly go to zero above a certain frequency. If this effect is analyzed it is seen that the spurious is reduced by this vestigial frequency response because of two reasons. The first reason is that any energy at these higher frequencies assists in reducing the spurious. The second reason is that, for optimum spurious reduction, the highest frequency overtone which is passed by the modulator should have a smaller amplitude than indicated by the Fourier series expansion of the envelope. This may be seen by considering the analysis in Appendix III and examining the effect of reducing the percentage of modulation of the highest order overtone. This effect is considerably more important for high order harmonics.

It has been found, in practical installations, that for a signal bandwidth of up to 6 kc, a modulator, having a flat response or one equalized for a flat response of approximately 8 kc, can be used to produce signals having the worst spurious amplitude down 30 to 35 db relative to one of the two equal desired tones.

Discussion of Practical Installations of Envelope Elimination and Restoration Systems

Fig. 2 is a picture of a commercial single-sideband envelope elimination and restoration transmitting adapter. This adapter may be used to adapt an amplitude modulated transmitter to single-sideband service. The phase modulation component of the single-sideband wave is fed to a low level rf stage of the transmitter. The AM component of the single-sideband wave is fed from the adapter to the audio input of the transmitter. Aside from the installation of a connection for feeding the low level rf stage, no modification of the transmitter is necessary. This adapter may be used to produce independently modulated upper and lower sidebands and is being used in a number of transoceanic multichannel teletype circuits.

A similar model of the single-sideband transmitter adapter may be used for broadcast relay service. This adapter has been used in conjunction with a 100-kw AM transmitter to produce a 400-kw peak envelope single-sideband signal. We understand that this is the most powerful single-sideband transmitter in operation.

No attempt has been made to minimize the size of this equipment and certainly appreciable reduction in size and weight can be accomplished by use of conventional miniaturization techniques.

The average spurious output of systems using these adapters is from -32 to -35 db relative to the amplitude of one of the two equal tones. The best measurement of a practical 40-kw peak envelope power transmitter utilizing this system was slightly better than -40 db.

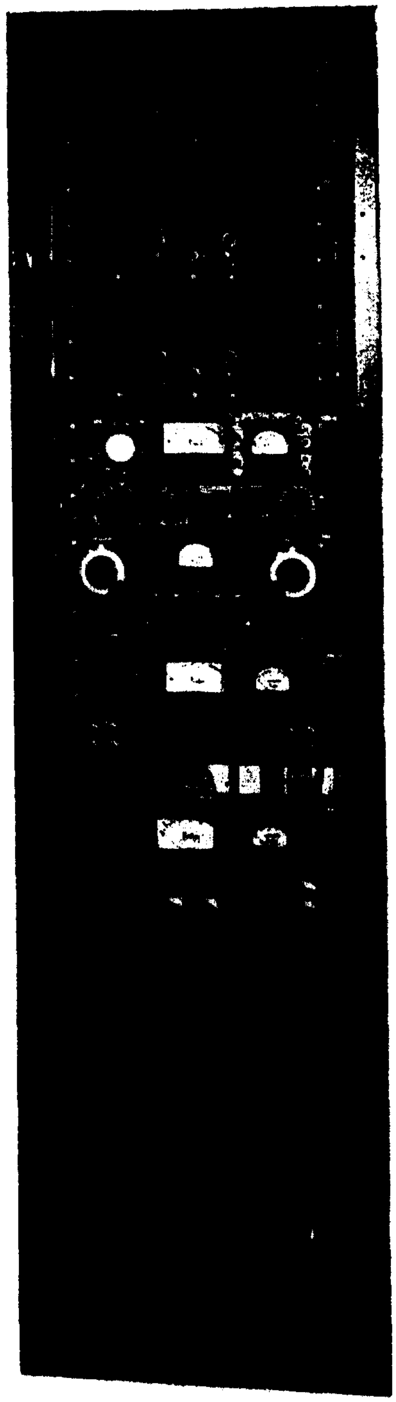


Fig. 2—SSB53-2A. Kahn Research Laboratories' twin sideband adapter.

Résumé of Advantages of Envelope Elimination and Restoration Systems

The advantages of the envelope elimination and restoration system are as follows:

1) The envelope elimination and restoration system produces approximately 2.5 times the power output, as does the linear amplifier system, for a given total plate dissipation.
2) The envelope elimination and restoration system may be used to adapt existing high quality transmitters without any design change of these transmitters. The peak envelope rating of such a system is from 3 to 4 times the carrier rating. Of course, the system may also be used as a component part of new transmitters.
3) The envelope elimination and restoration system is relatively noncritical because Class C amplifiers may be used.
4) Frequency multiplication may be used in the envelope system simplifying design.
5) The envelope elimination and restoration system makes practical low-cost high-powered, 20-kw peak envelope power or more, single-sideband transmitters. In the linear system, each additional stage introduces distortion and this makes it very difficult to obtain satisfactory spurious figures from high-powered transmitters. Also, the high efficiency of envelope elimination and restoration type transmitters is of considerable economic importance.
6) At the present time there are no very high-powered linear amplifier type single-sideband transmitters available, and for such requirements, the envelope elimination and restoration system appears to be the only practical solution.

Appendix I

Comparison of Linear and Envelope Elimination and Restoration Single-Sideband Transmitter Efficiencies

In order to compare the efficiency of the two systems, we will first derive an equation for efficiency of the linear amplifier. We will assume that the standard two equal tone signal is amplified by both systems because power and distortion ratings are generally based upon this specific waveshape.

The efficiency of a Class B linear amplifier is a linear function of the output voltage. (This functional relationship may be established by noting that output power is proportional to the square of the output voltage, yet the voltage from the plate power supply is constant and the current from the power supply is a linear function of the output wave of the amplifier. Therefore, since the output power varies as a square of the output voltage and the power input is merely a linear function, the efficiency must also be a linear function in order to establish the correct product function.)

Let us assume that the linear amplifier is used to amplify a signal composed of two equal amplitude tones and produces a 1-watt peak envelope power output. The average power, P_0, is therefore $\frac{1}{2}$ watt.[2] Since the envelope waveshape of a two equal tone wave is a full wave rectified sine wave and since the efficiency of a linear amplifier is a linear function of signal voltage, the efficiency as a function of time η_t is:

$$\eta_t = k \sin \omega t \tag{1}$$

where ω is the difference in angular velocity between the equal tones and k is the efficiency of the linear amplifier when delivering peak output.

The plate dissipation at any instant, t, is:

$$P_{dt} = P_{it} - P_{0t} = \frac{P_{0t}}{\eta_t} - P_{0t} \tag{2}$$

where

P_{it} = the power input fed to the amplifier from the power supply.

P_{0t} = the desired power output from the tube which is fed to the tank circuit.

($P_{0t} = \sin^2 \omega t \times 1$ watt for a two equal tone wave having a peak envelope power of 1 watt.)

Therefore,

$$P_{dt} = \frac{\sin^2 \omega t}{k \sin \omega t} - \sin^2 \omega t. \tag{3}$$

The average plate dissipation P_d is:

$$P_d = \frac{1}{\pi}\int_0^{\pi/\omega} P_{dt}dt = \frac{1}{\pi}\int_0^{\pi/\omega}\left(\frac{\sin \omega t}{k} - \sin^2 \omega t\right)dt$$

$$P_d = \frac{2}{\pi k} - \frac{1}{2}. \tag{4}$$

Therefore, since the average power output in this case is $\frac{1}{2}$ watt, the efficiency of a linear amplifier when amplifying a two equal tone wave is

$$\eta = \frac{P_0}{P_0 + P_d} = \frac{1/2}{1/2 + 2/\pi k - 1/2} = \frac{\pi k}{4}. \tag{5}$$

We will assume that in the envelope elimination and restoration system the Class C modulated stage has a plate circuit efficiency of 80 per cent (coupling circuit losses are not considered in this comparison) and the Class B modulator stage has an efficiency of 55 per cent. The following calculations show an over-all efficiency of slightly over 69 per cent:

Let $P_0 = 0.5$ watt (1 watt peak envelope power)

[2] The fact that the peak envelope rating of a two equal tone wave is equal to two times the average power rating may be confirmed as follows: consider that each of the two equal amplitude tones has an rms amplitude of one-half volt developed across a one ohm resistance. Each of the tones would dissipate $\frac{1}{4}$ watt and the total power of the two tones would then be $\frac{1}{2}$ watt. The peak envelope power, however, occurs when the two tones are in phase and their combined amplitude would then be 1 volt rms so therefore their peak envelope power would be 1 watt.

$$P_d \text{ Class C stage} = \frac{0.5}{0.8} - 0.5 = 0.125 \text{ watt}$$

Since, for a 0.5 watt SSB signal (1w PEP) there is 0.095 watt in the AM component.

$$P_d \text{ Class B} = \frac{0.095}{0.8 \times 0.55} - \frac{0.095}{0.8} = 0.0971 \quad (6)$$

$$\text{Total } P_d = 0.125 + 0.097 = 0.222 \quad (7)$$

$$\eta = \frac{P_0}{P_0 + P_d} = \frac{0.5}{0.5 + 0.222} = 69.2 \text{ per cent} \quad (8)$$

Appendix II

Power Output of a High Level Modulated Transmitter Converted to Class B Linear Operation

If we assume that the transmitter to be modified utilizes high-level modulation and that the modulated stage plate circuit efficiency is 80 per cent, then the plate dissipation, P_d, of the stage is:

$$\begin{aligned} P_d &= \frac{3}{2} P_{\text{carrier}} \frac{(1-\eta)}{\eta} \\ &= \frac{3}{2}\,\frac{0.2}{0.8} P_{\text{carrier}} \\ &= 0.375\, P_{\text{carrier}}. \end{aligned} \quad (9)$$

It was shown, in Appendix I, that a reasonable figure for the plate circuit efficiency of the linear single-sideband amplifier is 47.1 per cent. Therefore, the average power output, $P_{SSB\ av}$, of a transmitter altered to linear SSB operation is:

$$\begin{aligned} P_{SSB\ \text{av}} &= \frac{\eta}{1-\eta} P_d = \frac{0.471}{1-0.471} 0.375\, P_{\text{carrier}} \\ &= 0.334\, P_{\text{carrier}}. \end{aligned} \quad (10)$$

For a two equal tone single-sideband wave, the peak envelope power is equal to two times the average power. Therefore, the peak envelope power output of a transmitter modified for linear amplifier operation is approximately 0.67 times the carrier power output rating of the unmodified transmitter.

Appendix III

Modulator Frequency Response Requirement

The following analysis is accomplished in two segments. In the first part of the analysis the spectrum of the phase modulation component of the single-sideband wave is determined. This is the signal fed to the modulated stage in the envelope elimination and restoration system. In the second part of the analysis the phase-modulated wave is mathematically modulated by the components of the envelope of the two-tone single-sideband wave that are within the frequency response of the modulator. In this manner it is possible to calculate the amount of spurious produced when the modulator can pass only a restricted number of overtones of the envelope function.

Part 1

The method to be used for determining the spectrum of the phase-modulated component of a two equal amplitude tone wave was described in 1953 [5]. This method is based upon the fact that a limiter is an amplitude modulator which modulates the input wave by the inverse function of the envelope of this input wave.

The method may be outlined in the following series of steps.

1) The signal wave fed to the limiter is fully described as to the amplitude, frequency, and relative phase of the spectrum components.
2) The envelope function, $F(t)$, of the input wave is determined.
3) The inverse function of the input envelope function, $1/F(t)$, is next calculated. This is the envelope-limiter gain function, $ELGF(t)$.
4) The Fourier series describing the envelope-limiter gain function determined in step 3 is calculated.[3]
5) Each individual input signal component described in step 1 is amplitude modulated (multiplied) by the Fourier series of the envelope-limiter gain function. The resulting spectrum is the desired output of an ideal limiter and therefore it is the phase-modulation component of the input wave described in step 1.

In accordance with the above procedure, the following calculations may be made.

Step 1: The frequency components of the input wave, to the limiter, are shown in Fig. 3, line 1. Besides these two equal tone components there is assumed to be a noise component which, in the analysis, is made to approach zero. It is assumed that at zero reference time the two tones are exactly out of phase.

Step 2: The amplitude modulation component of the input wave is shown in Fig. 4. In order to simplify the analysis, it is assumed that the bottom part of the wave is a straight line as shown in the figure. Actually the bottom of the wave is not perfectly flat but since this portion of the wave is made to approach a limit of zero this assumption does not affect the accuracy of the analysis. The envelope function may be defined as follows:

$$\begin{aligned} F(t) \approx {} & [N]_0^{\epsilon} + [S \sin\theta]_{\epsilon}^{\pi-\epsilon} + [N]_{\pi-\epsilon}^{\pi+\epsilon} \\ & + [-S \sin\theta]_{\pi+\epsilon}^{2\pi-\epsilon} + [N]_{2\pi-\epsilon}^{2\pi}. \end{aligned} \quad (11)$$

Step 3: The envelope-limiter gain function, $ELGF(t)$, which is the inverse function of step 2, is determined.

[3] In many cases, it will be less laborious to do step 4 before step 3.

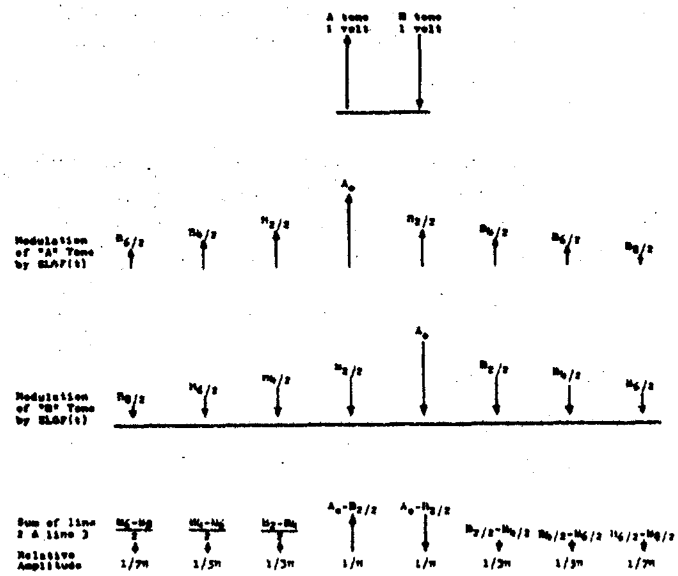
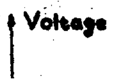


Fig. 3—Spectrum diagram showing calculation of two-tone phase modulation component



$$A_0 = \frac{1}{\pi}\int_0^{\pi} ELGF(t)d\theta = \frac{1}{\pi}\left[\int_0^{\epsilon}\frac{d\theta}{N} + \int_{\epsilon}^{\pi-\epsilon}\frac{d\theta}{S\sin\theta} + \int_{\pi-\epsilon}^{\pi}\frac{d\theta}{N}\right]$$

$$= \frac{1}{\pi}\left[\frac{2\epsilon}{N} + \frac{1}{S}\log\left\{\frac{\sin\theta}{1+\cos\theta}\right\}_{\epsilon}^{\pi-\epsilon}\right]. \qquad (13)$$

Due to the choice of fundamental frequency, all odd harmonics are equal to zero. The following equation defines the B_n Fourier series components where n is an even integer.

$$\frac{Bn}{2} = \frac{1}{\pi}\int_0^{\pi} ELGF(t)\cos n\theta d\theta$$

$$= \frac{1}{\pi}\left[\int_0^{\epsilon}\frac{\cos n\theta d\theta}{N} + \int_{\epsilon}^{\pi-\epsilon}\frac{\cos n\theta d\theta}{S\sin\theta} + \int_{\pi-\epsilon}^{\pi}\frac{\cos n\theta d\theta}{N}\right]$$

$$= \frac{1}{\pi}\left[\frac{2\sin n\epsilon}{Nn} - 2\int_{\epsilon}^{\pi-\epsilon}\frac{\sin(n-1)\theta d\theta}{S}\right.$$

$$\left.\int^{\pi-\epsilon}\cos(n-2)\theta d\theta\right]$$

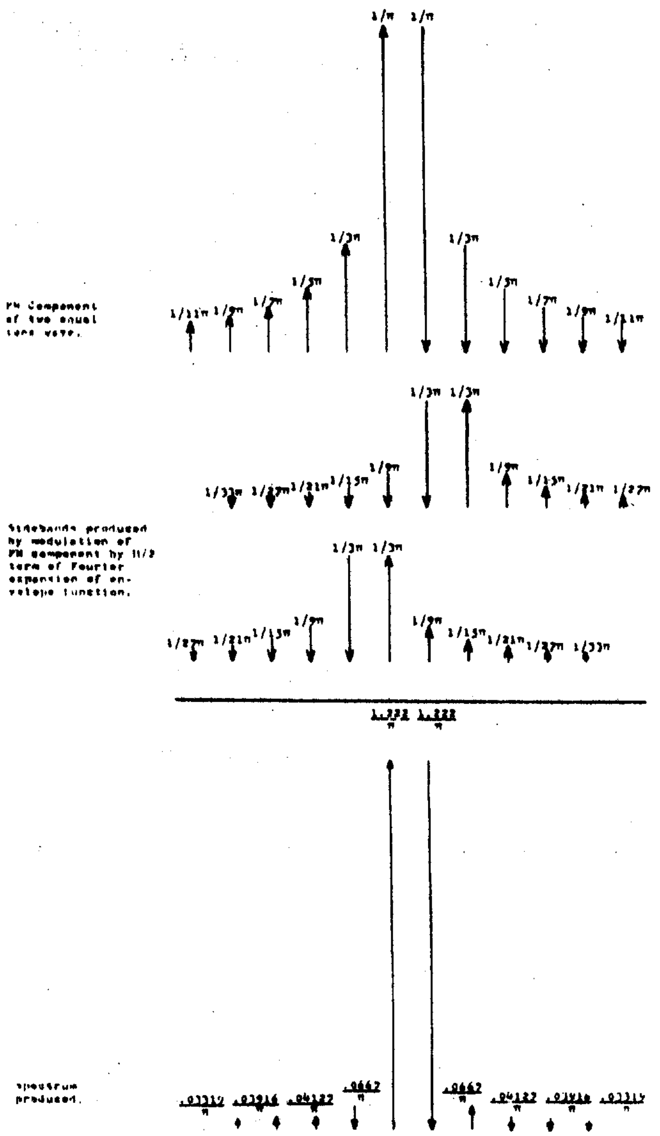


Fig. 5—Calculation of spectrum created when envelope elimination and restoration system is used with a low-fidelity modulator capable of passing only the fundamental beat note.

the envelope limiter gain functions, as shown in Fig. 3, lines 2 and 3. The result of this modulation process is then summated as shown in Fig. 3, line 4. It should be noted that, since the various sideband components are equal to a difference between B_n and B_{n-2}, the resulting spectrum may be readily determined to a very high order of precision by use of (16).

The result of this first part of the analysis is the phase-modulation component spectrum of a two equal tone wave. In addition to its application to single-sideband analysis, this result is of interest to other fields of physics.

Part 2

As mentioned above, the second part of the analysis requires the calculation of the effect of amplitude modulation of the phase modulation spectrum by the Fourier series components of the envelope function of the two equal tone wave. The envelope function of the two equal tone wave is exactly equivalent to that of a full wave rectified sinewave and may be expanded into the following Fourier series:

$$e = \frac{2E}{\pi}\left[1 + \frac{2}{3}\cos 2\theta - \frac{2\cos 4\theta}{15} + \frac{2}{35}\cos 6\theta \right.$$
$$\left. \cdots (-1)^{n/2+1}\frac{2\cos n\theta}{n^2-1}\right] \tag{19}$$

where n = even integer.

The result of modulation by merely the fundamental component of the Fourier series is shown in Fig. 5. Thus, it is seen that the worse spurious component is 25.3 db down, relative to one of the two equal tone waves. The results of similar calculations for modulators with better frequency responses are shown in Table I.

Acknowledgment

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POWER-side® COMPATIBLE AM/SSB BROADCASTING SYSTEM

by Leonard R. Kahn (M 1953, F 1961)

Leonard R. Kahn was awarded the Armstrong Medal at the 1980 Annual Awards Banquet in recognition of his work in AM stereo, independent sideband, time diversity, voice processing, and other advanced electronic techniques. He presented an outstanding address in response to the award in which he urged a reform in the U.S. patent system. He is president of Kahn Communications, Inc.

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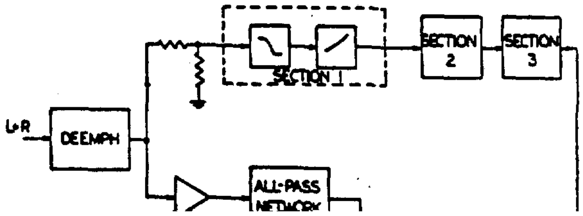
ABSTRACT -- The Independent Sideband system of AM

The optimum form of amplitude modulation is single-sideband (SSB) with reduced or suppressed carrier. SSB is the most rugged form of analog modulation and also occupies the least bandwidth. While the advantages of SSB were known by many of the pioneers of AM broadcasting, the complexity of SSB receivers restricted SSB's use to commercial, military and amateur applications. However circuit

A *POWER-side* wave is an AM wave having at least a substantial part of one sideband raised in level and the other sideband reduced in level, so that the total envelope modulation is unaltered. The stronger sideband is transmitted free of pre-emphasis, but the weaker sideband incorporates substantial pre-emphasis in order to insure full compatibility with center (carrier) tuned receivers.

Thus, *POWER-side*, while similar to Compatible Single Sideband[1] (CSSB) in use in the air-to-ground communications, is really an independent sideband, Kahn/Hazeltine type, AM stereo wave. (Indeed, *POWER-side* transmission can be implemented using either of the two FCC type-accepted Kahn Communications' stereo exciters (models STR-77 or STR-84) and a special audio processor.)

Thus, a signal with relatively flat frequency response should appear at the output of the de-emphasis circuit. The output of this circuit feeds an attenuator which reduces the audio level so that the signal has a level that will produce a weaker sideband approximately 15 db below the stronger sideband.



For example, if it is desired to enhance the lower-sideband, the output of the "all-pass" network is connected to the L input of the exciter and Section 3 output is connected to the R input. The stereo exciter causes the transmitter to produce the desired *POWER-side* RF wave.

It should be noted that a "stereo effects" wave may be added to the audio signal feeding the weak sideband so as to enhance the wave received by stereo listeners. The "stereo effects" signal can take many forms[2], including a special stereo component or certain stereo sounds such as "crowd noise" for a sporting event. (A future paper is planned to discuss further *POWER-side* developments as well as those pertaining to stereo transmissions effects.)

Sideband Tuning

The term "Sideband Tuning", as used in the following, is defined as the tuning of a receiver so as to favor the desired sideband of a *POWER-side* wave. When radios with reasonably flat IF selectivity characteristics are used, one edge of the receiver's passband will fall at approximately the station's carrier frequency in the same fashion as when a conventional SSB receiver is tuned to an SSB wave.

Listeners tuning to a *POWER-side* signal will naturally tune to the stronger sideband because it is louder. Early tests on Compatible Single-Sideband (CSSB) showed that the amount of sideband tuning is a function of the signal-to-noise ratio. The poorer the signal-to-noise ratio the further the listener will tune over towards the sideband and away from the carrier in order to improve intelligibility.

It has been experimentally demonstrated that the optimum amount of "sideband tuning", for typical narrowband AM radios, is of the order of 2.2 to 3 kHz. The actual amount of "sideband tuning" used is a fuction of the receiver's selectivity characteristic and the cleanliness of the *POWER-side* signal.

Thus, stations that wish to obtain the full benefits of "sideband tuning" will find it necessary to transmit clean signals, thus avoiding negative-going overmodulation, harsh audio-processing procedures and significant amounts of incidental phase modulation in their transmitters[3]. An important by-product of *POWER-side* operation is that all stations using the system will find it advantageous to improve their signal purity, reducing splatter and other sources of adjacent channel interference. (It is pointed out below that *POWER-side* also effectively reduces the so-called "carrier beat" co-channel interference effect.)

The optimum "sideband tuning" point (for a perfect *POWER-side* signal) is the same as it would be for conventional single-sideband (SSB) operation; i.e., tuned to the desired sideband with one of the receiver's passband edges at the carrier frequency.

As an example, assume that the receiver's IF passband is 6 kHz. It should theoretically support 3 kHz audio response when center or carrier tuned to a dsb AM wave, and 6 kHz when tuned to an SSB signal. (Unfortunately, for the AM broadcast industry, current (1988) receivers with 6 kHz passbands may be considered to have reasonable bandwidth and receivers with 4.4 kHz bandwidths are not unusual!) Experiments with a number of *POWER-side* stations show that tuning 2.2 kHz to 3 kHz from the carrier towards the stronger sideband turns out to be an optimum "sideband tuning" point, providing 4.4 to 6 kHz (-6 db) audio fidelity.

It is interesting to note that the matched filter concept of Information Theory would lead to a similar conclusion. In other words, since modern broadcast receivers have such a narrow band characteristic, the *POWER-side* signal better matches typical AM receivers. Thus, the implementation of *POWER-side* signals is consistent with the Matched Filter theory.

Accordingly, typical narrowband AM radios better match one sideband of a *POWER-side* wave than they match the two sidebands of the conventional dsb AM waves which they were designed to receive. In any case, "Sideband Tuning" to *POWER-side* signals, offers almost an effective 2-to-1 gain in frequency response for typical narrowband home and portable radios.

Reduction of Sideband Cancellation Effects

The classical amplitude modified wave has a serious weakness. The two sidebands of an AM wave are of equal amplitude, thus making the wave particularly sensitive to the relative phase of its three components. For example, if the carrier is rotated relative to the sidebands by 90 degrees, the wave is converted from a pure amplitude-modulated wave to a form of phase modulation (quadrature modulation) where there are no desired signal components present in the envelope of the wave.

In other words, the fact that the sidebands are equal in amplitude makes it possible for the desired demodulated audio waves derived from the two sidebands to completely cancel under certain conditions, such as selective-fading multipath conditions, etc.

Since the sidebands of a *POWER-side* wave are unequal, it is a much more rugged wave.

For example, conventional equal amplitude sideband AM waves suffer from a complete loss of fundamental modulation whenever the carrier is shifted odd multiples of 90 degrees; i.e., ±90 degrees, ±270 degrees, etc. In comparison, the *POWER-side* wave loses only 2.7 db under these same conditions. (See FIG. 2)

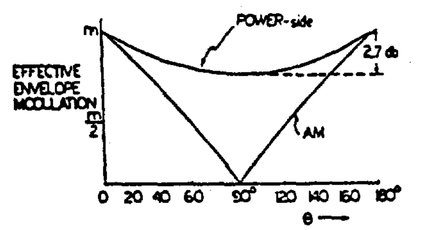
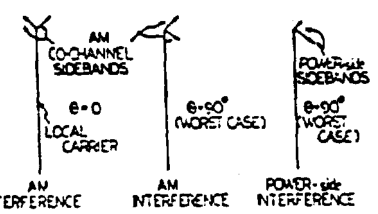


Figure 2



It is noteworthy that the use of a synchronous demodulator[4] does not, in any way, alleviate such losses of fundamental modulation.

It should also be noted that, unlike these advantages of *POWER-side* that are based upon "sideband tuning", the advantages based upon the reduced phase sensitivity of the *POWER-side* wave are available for all types of radios, including digitally tuned radios which center tune to the carrier frequency.

SUMMARY OF ADVANTAGES:

The advantage of the *POWER-side* system are of two basic types:

1) Those due to "Sideband Tuning"; and

2) Those due to reduction of sideband cancellation effects.

Obviously, in order to gain the "Sideband Tuning" advantages, listeners must use a receiver that can be tuned to a sideband such as: a) continuously tunable radios, or b) special digitally-tuned radios that can be stepped in no more than 2 kHz steps, or c) a new type of digitally-tuned radio specifically designed for "Sideband Tuning".

The advantages based upon the reduction of sideband cancellation effects are available with all types of receivers, including digitally-tuned radios which center tune to the carrier frequency. Generally, sideband cancellation effects are further enhanced by "Sideband Tuning", as the predetection spectrum of the wave is caused to have additional asymmetry.

Brief Description of the Advantages of "Sideband Tuning"

1) **Increased frequency response.** The frequency response of most receivers is limitd by the IF or RF selectivity characteristic. As discussed above, "Sideband Tuning" almost doubles the overall frequency response of narrowband receivers.

2) **Reduced adjacent channel interference.** "Sideband Tuning" causes splatter and adjacent channel carrier whistles to fall at a substantiallly lower point on the RF and IF selectivity curve. Furthermore, sideband tuning, by increasing the effective fidelity of the desired received signal, enhances critical sibilant sounds and other mid- and high-frequency sounds, raising their effective signal-to-interference ratios. Since sibilants are weak and generally are the first common sounds to be lost in interference, improving their level significantly improves intelligibility in fringe areas.

3) **Reduced co-channel interferences** due to "Sideband Tuning". (See section below treating "carrier beats", where a much more important advantage is described.) Assuming that the interfering AM station continues to transmit normal, equal amplitude sidebands, the desired station gains up to 4.7 db in addition to the other advantages of "Sideband Tuning".

The station that continues to utilize conventional AM transmission might be expected to gain even a greater advantage than its co-channel neighbor using *POWER-side*. The reason is that the *POWER-side* signal's weaker sideband is reduced approximately 10 db while its stronger sideband is raised only 3.5 to 4.7 db. The flaw in such reasoning is that, absent special *POWER-side* receivers, listeners should not be expected to "sideband tune" their receivers as would listeners to *POWER-side* equipped stations. However, if the two interfering stations, cooperate and both transmit *POWER-side* signals enhancing opposite sidebands, a very significant advantage can be achieved. In this case, as much as 15 db improvement in signal-to-interference ratio can be achieved with high selectivity receivers. (Also, as discussed below, they will both enjoy freedom from serious "beating" problems.)

On-the-air *POWER-side* operation by WMCA, New York, 570 kHz, favoring the upper sideband, and WSYR Syracuse, 570 kHz, favoring the lower sideband, has achieved very substantial interference reduction for both stations. Actually, WSYR has reported that at night, some seven miles from the WSYR transmitter and approximately 250 miles from WMCA, one is able to hear an intelligible signal from WMCA when using an independent sideband type AM stereo receiver.

4) **Less Critical Tuning.** Typically, receivers tuned to a *POWER-side* signal can be sideband tuned from as much as 3 kHz. Thus listeners can tune their radios from as much as 300 Hz on the "wrong side" of the carrier, to 3,000 Hz on the "correct" side, for a total of 3300 Hz spread. In comparison, typical AM signals, utilizing a similar pre-emphasis characteristic, would cause tuning to be limited to approximately ±300 Hz. Thus, the improvement is over five times the normal tuning range.

Brief Description of Reduction of Sideband Cancellation Effects

The relative insensitivity of a *POWER-side* wave, in comparison to the conventional AM wave, results in the following advantages which conform the ruggedness of a *POWER-side* wave:

a) Significant reduction in the selective fading distortion and the depth of the fades;[5]

b) Reduction in distortion in antenna nulls, as well as less loss of modulation in these critical locations[6]

c) Reduction of distortion and less loss of modulation due to reradiation from buildings and power lines:

d) And, most importantly, a dramatic reduction in the beat interference caused to other co-channel stations.

As pointed out above, *POWER-side* advantages a) through d) exist for all types of receivers, whether continuously tunable or digitally tuned.

Co-channel Interference Reduction

There are two distinct aspects to an analysis of the interference characteristics of modulation systems:

1) How does the modulation system influence interferences to other stations; and

2) How does the use of the system influence the interference heard by the station's own listeners?

The latter aspect has been treated above. It is now useful to consider how *POWER-side* operation will affect a station's co-channel neighbors.

Actually, in the long run the most important advantage of *POWER-side* operation may be that the system reduces co-channel interference effects. The reason for this important *POWER-side* characteristics can be best seen by examining the phenomenon commonly (and the author believes improperly) called "carrier beat".

A beating sound is most annoying and creates far more listener annoyance than does normal interfering speech or music. Thus, a clean voice signal (absent beating effects), say 30 db below a desired signal, produces far less disturbance than does a voice signal having the same level but suffering from beating effects.

The term "carrier beating" is generally used to describe this phenomenon. However, it is believed that this term is not truly descriptive of the problem. Typically, co-channel interference beat rates are less than a few Hertz. Such low frequency waves are greatly attenuated by the frequency response of a receiver's amplifier and loud speaker system. Indeed, listeners cannot hear such low-frequency sound waves even though they can feel very-low-frequency vibrations.

One can hear the slow variation in noise level caused by the variation of gain of AVC controlled amplifiers. However, even moderately severe co-channel interference of 20 db, causes the gain of the AVC controlled amplifiers to vary by only 1.74 db, and for interference 30 db below the desired signal the total variation is 0.5 db.

Actually the phenomenon that listeners do hear might best be called "sideband beat". The fact that sidebands beat under normal interference conditions can be understood by considering the following situation where:

1) the frequency of the desired (strong) signal is 900 kHz and the weaker co-channel carrier is 1 Hz higher, i.e. 900.001 kHz;

2) the desired signal is temporarily free of modulation, ("dead air"); and

3) the interfering signal is modulated by a 1 kHz tone.

Since the stronger (900 kHz) carrier dominates the demodulation process, (the envelope detector controls the switching function) the lower sideband will produce a significant demoduation product at a frequency of 999 Hz. The upper sideband produces a demoduation product having a frequency of 1001 Hz. Both of these equal amplitude waves easily pass through the receiver's audio system and are audible to listeners. The beat rate caused by the difference in the frequencies of the upper and lower sideband demodulated audio signals will be 2 Hz or *two times the carrier frequency difference.* (See Appendix A.)

Thus, under normal two-station co-channel interference conditions, the receiver output will be contaminated with two distinct audio signals having a difference in frequency of two times the carrier error.

Referring to FIG. 2, it is seen that conventional AM waves suffer a wide range of effective modulation, from full to complete nulls. On the other hand, a simplified analysis shows that a *POWER-side* wave only suffers a total variation of 2.7 db under the same condition.

In order to experimentally verify the reduction of co-channel beat type interference, a simple, but convincing, experiment was performed. A multi-system AM stereo "boom box" type portable radio, Sanyo model MW-250, operating in the monophonic mode, was tuned to two *POWER-side* stations (WMCA 570 kHz New York, and WTHE 1520 kHz Mineola, Long Island) at Kahn Communications' laboratories in Westbury, New York.

The output of a Hewlett Packard model 606B signal generator was loosely coupled to the input of the Sanyo MW-250 receiver. One of the two *POWER-side* stations was tuned in and the signal generator was adjusted to match the received carrier frequency within 2 Hz.

The output level of the signal generator was adjusted for maximum beat effects, indicating that the signal generator was producing the same signal strength as the received broadcast signal. The output attenuator of the signal generator was then switched, so as to raise the level of the signal generator by 20 db. This properly simulated a strong unmodulated local signal being interfered with by a *POWER-side* signal.

The resulting audible interference from voice and music signals was almost completely free of any beat-type phenomenon.

For comparison, the receiver was tuned to WOR, a New York station transmitting a conventional AM signal and the same procedure produced the very annoying conventional beat-type sound. It is believe that this simple test produced excellent substantiation of the reduction of the so-called "carrier beat" phenomenon by use of *POWER-side* transmission.

By reducing the sensitivity of the AM wave to "Sideband Beating", the widespread implementation of the *POWER-side* system should significantly reduce co-channel interference effects.

POWER-side and Platform Motion

It is important to report that asymmetrical spectrum characteistics of a *POWER-side* wave should reduce one of the basic weaknesses of phase-separated type AM Stereo systems; i.e., the Motorola, Harris and Magnavox systems. (Not the Kahn/Hazeltine ISB AM Stereo system, which is properly classified as a frequency-separated system and which does not suffer from such problems.) Phase-separated type AM stereo systems can, under certain conditions, produce a serious form of stereo image distortion which the author has called "Platform Motion". "Platform Motion" may be defined as the undesirable motion of a stereo image back and forth between the left and right sides.

(The significance of "Platform Motion" cannot be exaggerated and it is indeed the main reason why all stereo receivers designed to receive phase-separated type AM stereo signals must incorporate protection circuitry to switch to monophonic reception under adverse reception conditions. Conversely, receivers designed to receive AM Kahn/Hazeltine system stereo signals, which are free of "Platform Motion", can remain in the full stereo mode under all conditions of reception, insuring stereo coverage equal to the monophonic coverage of the station.)

Platform Motion is created by two main mechanisms:

1) **Multi-path transmission.** In this case, the desired signal reaches the receiver via two paths, such as reradiation from buildings and power lines or from close-in skywave/groundwave paths. (Such groundwave/skywave paths have been reported as close in as a few miles from the transmitter, severely limiting the stereo coverage of the station.) This type of interference causes the desired audio signal to move and is the most serious form of Platform Motion. It can be called "Strong Platform Motion".

2) **From co-channel interference.** In this case, the interference appears to swing back and forth from left to right and can be called "Weak Platform Motion". The net result is a substantial increase in the effect of the interference, because the interference "waves" at the listener.

If the co-channel interfering station operates with *POWER-side*, this second type of stereo image distortion, i.e., "Weak Platform Motion" can be significantly reduced by the interfering station transmitting a *POWER-side* signal instead of a conventional AM signal.

By reducing the sensitivity of the equal sideband AM wave to the phase relationship between the carrier and the sidebands, one type "Platform Motion" should be significantly reduced[7]. The type reduced may be called "Weak Platform Motion" because it is a less important type of platform motion and is created by weak co-channel interference. (See Appendix B.)

Unfortunately, the widely reported close-in skywave/groundwave platform motion, and other "Strong Platform Motion" effects due to power-line and building reradiation, are not alleviated because *POWER-side* is not compatible with phase-separated type AM Stereo systems. Thus, radios designed to receive phase-separated type AM stereo signals will still require protection circuitry to disable stereo reception in less than good reception conditions.

Adjacent Channel Interference

Obviously any modulation procedure has to be evaluated as to its impact on the interference it causes to other stations and also how sensitive the system is to interference from other stations.

It has been pointed out above that substantial advantages accrue to listeners of *POWER-side* stations, whether the station is subjected to co- or adjacent-channel interference. Furthermore, it is shown elsewhere in this paper that *POWER-side* stations are good co-channel neighbors, in that the *POWER-side* wave dramatically reduces co-channel "beat" interference.

Now the question is: what does *POWER-side* operation do to adjacent channel neighbors? Since one sideband is made stronger than the sideband of a normal double-sideband AM wave and the other side is made weaker, one might expect increased interference to neighbors on the strong side of the channel and a reduction of interference to neighbors on the weak side.

Actually, neither sideband of a *POWER-side* signal increases adjacent channel interference. Indeed, stations on both sides, in comparison with normal AM Stereo operation or even normal mono operation, should experience, in practical situations, an improvement in interference. Why this is

Since the audio processing for *POWER-side* significantly reduces the strength of the stronger sideband over these severe L only, or R only, stereo tests, *POWER-side* fully complies with FCC rules and regulations.

2) The stronger sideband of the *POWER-side* wave is not pre-emphasized. Since pre-emphasis can increase splatter by as much as 10 to 15 db at 10 kHz, this elimination of pre-emphasis on the strong sideband is a significant factor.

3) As mentioned above, the *POWER-side* effect is eliminated at 7.5 kHz by the action of filters in the stereo exciter. Actually, the additional pre-emphasis on the weak sideband causes the weaker sideband to achieve level equality with the stronger sideband at approximately 5 kHz. Thus the impact of *POWER-side*, in terms of causing adjacent channel interference, is restricted to sideband components within ±5 kHz of the carrier.

4) A *POWER-side* signal requires less pre-emphasis because the *POWER-side* wave is less sensitive to loss of modulation caused by phase distortion. The typical RF and IF selectivity characteristic of an inexpensive receiver introduces substantial phase distortion. Therefore, in order to achieve a reasonable brightness of sound quality an equal-sideband AM wave requires substantially more pre-emphasis than does a *POWER-side* wave. Since the amount of pre-emphasis used directly increases splatter interference, a *POWER-side* signal, for a given brightness of sound, should produce substantially less adjacent channel interference.

As an example, if the phase distortion of the overall sytem, including the transmitting antenna, receiving antenna, and the RF and IF selectivity circuits in the receiver, create a phase distortion of 60 degrees at say 6 kHz (12 kHz IF bandwidth), a conventional AM wave will have 25% efficiency in terms of sideband power utilization. Under the same conditions, a *POWER-side* wave provides approximately 64% efficiency. In other words the effective modulation of the conventional AM wave is 50% and the effective modulation of the *POWER-side* wave is 79.9%.

5) There is also a practical consideration that should substantially reduce adjacent channel interference when broadcasters implement *POWER-side*. This may be seen by recognizing the fact that *POWER-side* stations derive a substantial portion of the system's advantages because listeners can "sideband tune" their radios. "Sideband Tuning" advantages are a function of the amount of off-tuning listeners find advantageous. Thus the "cleaner" the POWER-